Where Real Options Might Really Work

Neal A. Lewis, University of Bridgeport
Ted G. Eschenbach, TGE Consulting
Joseph C. Hartman, University of Florida
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Abstract

Proposed projects are often justified financially by using traditional discounted cash flow tools such as net present value and internal rate of return. These methods have been criticized because they do not recognize the fact that management has the option of making changes in the project if the financial situation changes. Real options analysis is a tool that has been used to assign a value to managerial flexibility. Theory states that the true value of a project can be represented by the sum of the net present value plus the option value, yielding an expanded net present value (ENPV). One area where real options analysis has been used with some success is in the area of natural resources, where the well defined volatility of commodities prices can be used to better predict the volatility of future events. This paper explores an example where real options should provide helpful information through the use of a simplified oil exploration case study that would be suitable for use in the engineering classroom. The case study represents a method to introduce the subject of real options using a realistic application.

Introduction

Discounted cash flow techniques are the most widely used methods for determining the value of a project. These techniques include net present value (NPV), internal rate of return (IRR), and others. NPV is determined by discounting forecasted future cash flows by a required rate of return, as shown in equation (1).

$$NPV = -I_0 + \sum^{T} \frac{FV_N}{(1+r)^N} \tag{1}$$

Despite being widely embraced by academia and industry, discounted cash flow (DCF) has been criticized for biasing evaluators toward conservative conclusions [1]. Good ideas are sometimes not pursued because DCF techniques assume that expenses and cash flows occur without the possibility of being changed. In reality, management has options of making changes during the life of the project, especially during the early stages.

Real options analysis is a tool intended to place a value on the managerial flexibility in future choices [2]. The theoretical foundation for real options begins with options on financial securities. The extension into real options can be illustrated by an oil firm that continues to lease potential development tracts even though development is not currently economic. Paying for the real option (the lease) can be the best choice, because of the possibility that improved technology, higher prices, or other items will make the development economic in the future.

Projects with NPVs that are very high are considered good investments, and can justify investment without further analysis. Projects with NPVs that are negative are usually abandoned because they will not deliver the required return. Projects with an NPV close to zero require additional effort to determine whether they should be funded or abandoned. The decision often takes one of three forms: fund the project, abandon the project, or keep the 'option' open, keeping the project alive without funding it. In real options analysis, the option creates an expanded net present value, defined as [3]:

$$\text{ENPV} = \text{NPV} + \text{Option Value} \tag{2}$$

When NPV is large, there is no need to determine an option value. When the NPV is highly negative, the project should be abandoned; no option value will justify the project. Real options have their application only in those projects where the NPV is close to zero, where there is uncertainty, and where management has the ability to exercise their managerial options.

There are five variables that are involved in determining an option value; the first four of these are the same as those used to determine NPV: *S*, present value of future net cash flows; *X*, investment costs; *T*, the time horizon; *r*, interest rate; and σ, volatility of the project's rate of return. The Black-Scholes pricing model [4] can be used to determine the value of a simple call option. This model has been expanded to include the cost of waiting as shown in equations (3) and (4).

$$C = (S_0 - W)\phi(d_1) - Xe^{-rT}\phi(d_2) \tag{3}$$

$$d_1 = \frac{\ln\left({(S_0 - W)}/{X} \right) + \left(r + {\sigma^2}/{2} \right) T}{\sigma\sqrt{T}} \qquad\qquad d_2 = d_1 - \sigma\sqrt{T} \tag{4}$$

where $\phi(d_x)$ is the cumulative standard normal distribution of d_x.

W is the cost of waiting

The value of simple options can be quickly determined using the Black-Scholes model, but the math becomes very complex if the problem becomes complicated. Binomial lattices can also be used to determine the value of financial and real options, but values approach those of the Black-Scholes model; so only that model is addressed here.

Case Study

An oil exploration company is considering leasing a plot of land and drilling an oil well. The well will have characteristics that are typical of this company's projects, and the equipment sizing, outputs, and costs are well understood. The characteristics of the project are shown in Table 1.

Table 1. Oil Well Project Information

First cost	\$57 million	Oil price	\$50/bbl
Salvage cost	\$10 million	Oil price volatility/yr	35%
Output, yr 1,10^6 bbls/yr	0.60	Project volatility, %	To Be Determined
Well depletion rate/yr	15%	Project delay	Up to 2 years
Operating costs	\$10/bbl	Risk-free rate	5%
Hurdle rate, %	16%		

The first step is to determine the NPV of the project. Note that in addition to the initial investment of \$57 million, there will be an additional salvage cost of \$10 million at the end of the project to return the site to its original condition. The output of the well will begin in Year 2, and then it declines at 15% per year. The well will produce for seven years before it is shut down. Cash flows are shown in Table 2.

The NPV can be determined using equation (1) given the hurdle rate of 16%. If the project were started now, it would have an NPV of −$0.46 million. The well is not worth starting given the current price of oil.

Table 2. Project Cash Flows, millions of dollars

Year	Invest Now	Delay (up to 2 years)
0	−57.00	0
1	0	0
2	24.00	−57.00
3	20.40	0
4	17.34	24.00
5	14.74	20.40
6	12.53	17.34
7	10.65	14.74
8	9.05	12.53
9	−10.00	10.65
10		9.05
11		−10.00

Delay Option Formulation

As most of the examples we've analyzed with real options have led to questions about one or more points of "standard practice," this example has been selected as the best hope for a "good" example of the effectiveness of real options. The example presented here is analyzed along the lines of conventional practice. We do have unanswered questions about this approach, but it still is an effective example to describe conventional practice.

The company has several options. First, it could invest in the project; however, the NPV is negative, making this unattractive. Second, the company can abandon the project, as suggested by the NPV. Third, the company could keep the project open by paying a lease on the property, investing later only if prices increase enough in the future to make investment economical. By paying the lease, the company can pay a relatively small premium (the lease) to preserve the option of future investment. The question is: how much should the company be willing to spend to keep the option (the project) open by paying a lease?

The company should be willing to pay up to the expanded net present value (ENPV) to keep the option open. A simple delay option can be solved using the Black-Scholes model. In this case, we will delay the project up to two years, but can execute the option (implement the project) at any time up to the two-year expiration of the lease. This is known as an American option Equations (3) and (4) will be used to determine the value of the delay option. The value for S_0, the present value of the net cash flows, can be found with our existing data; this was used to find the NPV. The first cost is known with certainty. The interest rate is important because we are dealing with cash flows over a span of years. Two different interest rates are used; the hurdle rate and the risk-free rate. The NPV uses a hurdle rate, also known as a “market” interest rate. The Black-Scholes equation uses a risk-free rate.

The time variable is the time of delay. For financial options, a European option can not be exercised until it is mature. In real options, this is equivalent to waiting for an event to occur, such as the completion of a research study or approval from a regulatory agency. An American option can be exercised at any time up to its maturity date. The equivalent real option is waiting for conditions to improve, such as the price of oil increasing.

The volatility recognizes that we are dealing with uncertainty. Volatility is defined as the standard deviation of the rate of return of the project [4]. Many real projects will have several sources of uncertainty. In this case study, there is only one source of volatility, the price of oil. It is important to realize that the volatility of the project is not the same as the volatility of the input variables; the project volatility is not necessarily 35% simply because we have one input whose volatility is 35%. The project volatility must be estimated, and this is the most difficult variable to forecast with accuracy.

The Input Variables

Investment. The first cost is known to be $57 million. For simplification of the problem, we will assume that this is known with certainty, and that the value will not change if the project is delayed. However, if the project is delayed, then the first cost must be discounted to the present time. In determining the NPV, the investment is discounted using a hurdle rate (market rate), using discrete compounding. When determining the option value, the first cost is discounted using the risk-free rate, usually using continuous compounding.

Interest rates. Net present value is typically determined using a single hurdle rate, using discrete compounding. Financial options are typically calculated using a risk-free rate, using continuous compounding. Real options, unfortunately, uses a mixture of these, and the method depends on the author [5]. All real delay options problems begin with determining the NPV of the project. In most cases, this NPV is determined using traditional approaches. Luehrman [6] first proposed that costs are known with greater certainty than future revenues are, and that the risk surrounding project costs are less than the risks of the forecast revenue stream. For this reason, he suggested that costs be discounted using risk-free interest rates when determining the NPV for a real option project. This idea has been supported by Mun [7] and Park [8]. The idea is controversial, and has not gained wide support. This practice contradicts standard engineering economy methods of using a single interest rate. The use of the risk-free rate to discount the investment will provide a larger present value of the cost, thereby decreasing the option value and providing a more conservative recommendation.

For option valuation, interest rates may be applied using either discrete or continuous compounding. There is no uniform approach to using either discounting method when using real options. The business literature consistently uses continuous discounting, in keeping with their calculus-based approach to options analysis ([9] for example). Practitioner books are consistent in continuous discounting of future costs while using discrete discounting of future net cash flows [1,7]. The engineering economy literature uses both methods, and is not consistent. The use of discrete or continuous interest rates can have a significant effect on the value of the option, and the choice of compounding method can change the decision outcome. The issue is not academic; it can have a real impact on decision making [5].

Time and the PV of future cash flows. The time involved is the time of delay. European options deal with specific time intervals, and all calculations are based on the fixed time to maturity. American options can be exercised at any time. Robert Merton [10] pointed out that exercising an option early has no value unless there is a dividend (a loss in value due to waiting), which is consistent with financial options analysis. However, we have found that all deferral options on real projects have a cost of delay.

Option values are very sensitive to changes in the forecasted net cash flows. Many authors have pointed out that there is often value in delaying a decision, hence the value of a deferral option. What few authors point out is that there is always a cost involved in the delay of a real engineering project. If nothing else, projected revenues will be delayed, causing a decrease in their present value due to discounting. Of course, the value of delaying may outweigh the cost of waiting, but deferral costs must not be ignored as they are in much of the literature. The traditional view of a delay cost is to model it after dividends. However, the dividend model is rarely the correct model because it fails to accurately describe the nature of lost cash flows. Delay models must be matched to the details of the case being analyzed [11]. Including waiting costs is virtually a requirement for realistic engineering projects.

Waiting costs can be modeled for a European option without too much difficulty. Delays are known, and lost or deferred cash flows can be modeled based on the delay. In the present case, we have an American option, where the firm is waiting for the price of oil to increase to the point where it is economic to pursue the project. What is the waiting cost in this case? It depends on how long the project is delayed, at what price the project is implemented, and what occurs in the future.

If the current project were not delayed, there would be no cost of waiting (there would also be a negative NPV). If the current case were delayed the full two years, there would be a cost of waiting of $14.52 million, and there would still be a negative NPV. A smaller delay results in a smaller cost of waiting, but also a smaller option value. The traditional approach is to model the delay to its maximum length of time and to use the largest possible option value. The difficulty is that the result is the largest possible ENPV, inflating the true value of the option. The state of the art provides an option value that is too large, causing overly optimistic conclusions. How to determine the real value of a real American option requires further research.

Volatility. Determining financial option volatility is not a problem because it is based on the standard deviation of the logarithmic returns from the historical price of a stock. This is known information, with the only question being whether historical volatility will hold in the future. Oil price volatility increased dramatically during the large market fluctuations of 2008. Volatility for real options is determined based on the standard deviation of the projected rate of return of the project. This is not historical information, but forecasted data. The only way to determine the standard deviation of forecasted data is with simulation.

A number of approaches have been used over the years. The logarithmic cash flow method used for financial options can be applied to real options, but does not yield an accurate volatility. For a number of years, the stock proxy method was employed, where a traded stock having similar characteristics to the project was used as a proxy for the project's volatility. This was abandoned also, because company stocks rarely follow the risk profile of a single project. Management estimates are sometimes used, using optimistic and pessimistic forecasts [7,8].

Currently, the most widely used approach is the logarithmic present value of returns [1]. In this method, the estimated future cash flows are discounted to two present values, one for time zero and another for time 1. The natural log of the ratio of these is simulated using Monte Carlo analysis. For a summary of this method, see [12].

There is an enormous difference between the variability of a stock price and the variability of the present value of returns. When the price of a stock varies into "payoff" territory and the financial option is exercised, at that moment the entire value of the option is captured. The probability of this happening is based on the volatility. In stark contrast, with real options much of the variability may be based on cash flows whose variability continues after the option is exercised. The value of this continuing variability is <u>not</u> captured by the option.

Only volatility that can be captured should impact the value of the option. Volatility that comes from independent random variability that continues each year cannot be captured and should not be used to value the option. We have suggested [12] that volatility that can be *captured* be called *actionable* volatility. To differentiate between the two, we refer to previously calculated values as total volatility.

Solving the Problem

The first step in solving the problem is to determine the input variables, as shown in Tables 1 with the resulting cash flows shown in Table 2. Then discount future net cash flows using the hurdle rate and discrete (annual) compounding. Costs for the determination of NPV will also be discounted using the hurdle rate and discrete compounding, consistent with traditional engineering economics. Costs for determining the option value will be discounted using the risk-free interest rate and continuous compounding, consistent with the Black-Scholes model (and consistent with most users of binomial lattices).

Before the option value can be determined, the volatility must be estimated. The method of logarithmic present value of returns will be used, since this has recently been the most widely used method. The investment cost is not involved in this technique, but since we do not have variability of the investment, this is not a problem. The key variables are the future cash flows, determined by the price of oil, the operating cost, and the production of the well. The price of oil is determined to be only input variable having volatility (standard deviation of 35%). However, the oil price must vary in each year. The oil price is assumed to follow a lognormal distribution, since the price can not fall below zero. The oil prices are correlated 90% from year to year; the price in one year will tend to follow the price of the preceding year [13]. The correlation is important. Without it, each year's price would vary independently of preceding prices. Without correlated oil prices, there is no actionable volatility due to oil prices, and project volatility would be meaningless.

The details of the calculation are outside of the scope of this paper. The project's volatility is determined to be 43.5% annually, somewhat higher than the 35% volatility of the price of oil.

Black-Scholes results. Applying our input variables, including the newly determined volatility, we find an option value of $5.11 million. Added to the NPV of drilling a well now provides an ENPV of $4.65 million.

Binomial lattices. Binomial lattices were created to provide a simplified approach to option valuation [14]. They are more flexible and can be used to calculate more types of options, but a thorough description is outside of this paper's scope. Mun [7] provides excellent descriptions and examples for solving a variety of problems with binomial lattices.

Issues for the Classroom

Most undergraduate engineering economics courses are already full with important, basic tools and concepts. Real options analysis is an advanced tool that does not fit most introductory courses. At the undergraduate level, options analysis should probably be limited to making the student aware of its existence.

We believe that real options does have a role to play in advanced graduate courses, in intermediate or advanced economic analysis, or applied courses that focus on valuation or budgeting of advanced technology systems. While the use of options analysis remains controversial, it is a subject that the advanced engineering economics student should understand. If engineers are to take part in the debate, then we must first understand the methodology and test it on real world applications to projects.

Needed Research

1. We need to understand how to accurately determine the option value when the deferral timeline is fluid, as in an American option. This affects many projects, and the state of the art simply pegs the timeline to its maximum, providing inflated option and project values.

2. There continues to be great difficulty in calculating an accurate volatility coefficient, and there are nearly as many approaches as there are authors. We need consistency.

3. There are several inconsistent approaches to which interest rate and what type of discounting (discrete or continuous) should be used in calculating NPV and the option value. The literature needs to evolve a consistent approach.

4. If simple options such as the one described here require pages to calculate and there is little consistency in modeling choices, then what hope do we have of accurately calculating the value of complex options?

Conclusions

Even simple options such as the one described require extensive analysis and a number of assumptions. Simple options analysis is a complex tool that provides a slightly different perspective than traditional tools. Do we make better decisions because of real options tools? Is the value of the added information dependent on the assumptions we make? These questions are at the heart of ongoing research. In the oil well case, we can not specifically identify the cost of waiting for an American style option, and the calculated option value is suspect. What we know with certainty is that state of the art approaches provide us with an answer that is overly optimistic, and thereby not appropriate for use.

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About the Authors

Dr. Neal Lewis received his Ph.D. in engineering management in 2004 and B.S. in chemical engineering in 1974 from the University of Missouri – Rolla, and his MBA in 2000 from the University of New Haven. He is an associate professor in the School of Engineering at the University of Bridgeport. He has over 25 years of industrial experience, having worked at Procter & Gamble and Bayer. Prior to UB, he has taught at UMR, UNH, and Marshall University. Dr. Lewis may be contacted at the University of Bridgeport, 221 University Avenue, Bridgeport, CT 06604; 203-576-4569; lewisn@bridgeport.edu.

Dr. Ted Eschenbach, P.E. received the MCE degree in 1998 from the University of Alaska Anchorage. His masters in operations research and his doctorate in industrial engineering are from Stanford University. He is the principal of TGE Consulting, an emeritus professor of engineering management at UAA, and the founding editor emeritus of the *Engineering Management Journal*. He is the author or co-author of engineering economy texts currently published by Oxford University Press.

Dr. Joseph C. Hartman, P.E. received his Ph.D. in 1996 and M.S. in 1994 in industrial engineering from the Georgia Institute of Technology and his B.S. in general engineering from the University of Illinois at Urbana-Champaign in 1992. He is a professor in the Department of Industrial and Systems Engineering at the University of Florida and serves as department chair. His research interests are in economic decisions analysis and dynamic programming. He is an active member of ASEE, IIE, and INFORMS and currently serves as editor of *The Engineering Economist*.